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From Ecocide to Eco-ally: Picloram, Herbicidal Warfare, and Invasive Species, 1963-2005

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Abstract

Picloram is a powerful, persistent herbicide that has been in use since 1963. It has been used around the world for brush clearing, forestry, and maintenance, and was a key part of Amazonian deforestation. The United States and probably Portugal used picloram in wars in Vietnam and in Africa. Its use in war prompted strong censure and led to picloram's association with "ecocide" – ecological destruction. After Vietnam, US environmentalists continued to be highly critical of picloram's use domestically, but in the 1980s, in response to world-wide problems with invasive species as well as changes in the understanding of ecological health, many environmentalists came to embrace the use of herbicides as necessary for maintaining and restoring ecosystem health – as an eco-ally. The radical re-orientation of some North American environmentalists toward toxic chemicals like picloram as a way to combat invasive species shows the ecological contingency of environmentalism. Controversy between environmentalists about herbicides and invasive species revealed latent tensions between human health and ecosystem health, long-term and short-term environmental goals.

Rachel Carson's *Silent Spring* argued that humans should take a holistic, long-term view of their interactions with the ecosystems they live in, for both their own benefit and the benefit of their cohabitating organisms. Her infamous target was the persistent insecticide DDT, but she critiqued many pesticides. Although Carson's warnings were dire, her book was exceptionally optimistic. For one thing, she argued that the massive use of pesticides was simply unnecessary. Using small amounts of safety-tested pesticides along with non-chemical techniques would be more effective and cheaper than mass spraying. Her book, however, was optimistic in an even more fundamental way. The central theme of *Silent Spring* was that human health and ecological health were coextensive. There was no tension between human health and attempts to save organisms or habitats. What was good for the goose was good for humankind. By the same

token, there was no conflict in taking a long-term view of ecological health. Taking the long-term was essential, but it did not require putting humans or other organisms at risk in the short-term. There was, as an ecologist might put it, a mutualistic relationship amongst these goals. That perceived mutualism neither began nor ended with Carson, but her writing encapsulated it well. And that perception helped build a robust environmental movement made up of people who had differences in which goals they held most important and relevant, but who could nevertheless find compatible goals and common enemies.[1] As the history of the herbicide picloram shows, however, that comfortable mutualism did not always hold.

A year after the publication of *Silent Spring*, Dow Chemical company released its new herbicide picloram into a tumultuous world of rapid economic integration, expanding populations, and shifting ecosystem regimes. Picloram was born into a Cold War international order and a world of ascendant new social movements, among them national liberation and environmentalism. Plants were serious problems in this rapidly changing world. Perennial weeds plagued farmers, and brush encroached on grazing lands, hampering development. Economic integration depended on infrastructures – roads, power lines – but these required sustained control of plants in order to operate effectively. Plants were problems for other reasons as well. They could provide food and cover to insurgent forces fighting asymmetric wars against powerful states. And when these plants were invasive, they could also threaten the integrity of ecosystems. Picloram killed plants superbly. It was hundreds of times more toxic to plants than similar herbicides and much more environmentally persistent than them. Decades later, picloram was still considered the most powerful of the growth-regulating herbicides.[2] Because of these properties, picloram was used around the world.

This article will follow how the use of picloram and perceptions of it have changed over time. It begins in the US, then moves to other developed and developing countries, before returning to the US for an in-depth analysis of environmentalists' perception of picloram. In general, governments, businesses, and farmers quickly embraced picloram's powerful ability to transform landscapes. For these groups, picloram was a godsend. Picloram also became part of campaigns

[1] R. Carson, *Silent Spring*, Houghton Mifflin, Boston 1962.
[2] M. Pessarakli, *Handbook of Plant and Crop Physiology*, CRC Press, Boca Raton 2001, p. 503.

to develop poor countries, and it was used during wars in Vietnam and Africa. These uses affected how environmentalists in the US thought about the herbicide, with the result that within a few years of its release, environmentalists considered picloram an agent of "ecocide" – the environmental equivalent of genocide – a term the biologist Arthur Galston coined to oppose the use of herbicides in the Vietnam War. By the end of the twentieth century, however, many environmentalists accepted the necessity of herbicides to combat invasive plants. Picloram became one of the premier killers of invasive plants, recognized, however begrudgingly, as an important technology of ecological preservation and restoration – an eco-ally. Although a similar story could be told for some other herbicides, none have swung such a wide narrative arc from technology-as-destroyer to technology-as-restorer.

The metamorphosis of picloram from pariah to messiah among environmentalists is significant for several reasons. First, although there is an emerging literature on herbicidal warfare and its connection to environmentalism, virtually none of this discusses picloram in any detail. As I argue here, however, picloram was the herbicide of greatest ecological concern for Galston. The history of picloram helps show that it was concern about chemical *persistence* and *uncertainty*, not just the *scale* of use, that shaped ideas about ecocide. It also helps connect these concerns about herbicidal persistence to Carson's worries about the persistence of DDT.[3] Second, the metamorphosis of picloram resulted from the increasing problem of invasive species, and this shows the ecological contingency of environmentalism: As different plant species moved around and increased, environmentalists re-thought some of their most fundamental premises. Historians have generally understood ecological and socio-political changes as catalyzing the emergence of the environmental movement, but they have mostly looked to socio-political causes to understand how the movement has changed over time. Subsequent environmental changes have added to or amplified existing environmental concerns, but historians have not generally portrayed these as causing fundamental re-orientations of environmentalist ideas. The argument

[3] Both David Zierlier and Amy Hay have written excellent accounts of herbicidal warfare in Vietnam, but picloram is barely mentioned in either one. D. Zierler, *The Invention of Ecocide: Agent Orange, Vietnam, and the Scientists Who Changed the Way We Think About the Environment* University of Georgia Press, Athens (GA) 2011; A.M. Hay, "'A Kind of Mylai … Against the Indochinese Countryside': American Scientists, Herbicides, and South Vietnamese Mangrove Forests", in *Environmental Change and Agricultural Sustainability in the Mekong Delta*, M.A. Stewart, P.A. Coclanis (eds.), Springer Netherlands, Dordrecht 2011, pp. 69-81.

presented here, however, is that ecological changes catalyzed just such a re-orientation: The perception of toxic pesticides as beneficial, rather than just harmful to the environment.[4]

That some environmentalists embraced toxic pesticides as beneficial, however, was highly controversial, and that controversy revealed latent tensions between environmentalists. The US had always contained many different strains of environmentalism, shaped by class, race, geography, and history, and these differences created friction and disputes.[5] But these conflicts did not result from goals that were fundamentally incompatible. Rather they tended to reflect differences in priorities and strategy. However, the controversy over herbicides and invasive species was different: each side believed that the goals of the other side threatened their own fundamental goals. This, I argue, reflected tensions between human health and ecosystem health, and short-term and long-term goals.

The Development of Picloram

Picloram was Dow's most successful, early contribution to a class of herbicides called growth-regulators. Growth regulating herbicides revolutionized agriculture because they were systemic – an entire plant could be killed just by absorbing herbicide sprayed on one leaf – and they were often selective for certain types of plants. Growth regulators killed plants by mimicking plant hormones, causing the plant to grow itself to death. Previous to growth regulators, farmers used herbicides like sodium chlorate (Atlacide) and sodium arsenite that killed the contacted part of the plant. Before about 1890, farmers had almost no chemical controls for weeds at all.[6]

The first growth regulator was 2,4-D, which entered use in 1945. 2,4-D mimicked the plant hormone auxin, which allowed it to target dicots (broad-leaved plants, generally) while sparing monocots (grasses, generally). This was extremely important, since the main agricultural commodities – rice, wheat, barley, corn, rye and so on – were grasses, and most pasture and

[4] A. Rome, *The Bulldozer in the Countryside: Suburban Sprawl and the Rise of American Environmentalism*, Cambridge University Press, Cambridge 2001; S.P. Hays, B.D. Hays, *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955-1985*, Cambridge University Press, Cambridge 1989.
[5] R. Gottlieb, *Forcing the Spring the Transformation of the American Environmental Movement* Island Press, Washington, DC, 2005; A. Hurley, *Environmental Inequalities: Class, Race, and Industrial Pollution in Gary, Indiana, 1945-1980*, University of North Carolina Press, Chapel Hill 2009.
[6] F.L. Timmons, "A History of Weed Control in the United States and Canada", in *Weed Science*, 1970, pp. 294-307.

forage plants were grasses. In short, the herbicide could kill weeds but leave the crop untouched. In the late-1940s, another growth regulator, 2,4,5-T, emerged that was more effective at killing woody plants than 2,4-D. Herbicides are usually categorized by their chemical family. Herbicides in the same chemical family often have similar properties, but properties can also vary considerably with even very slight chemical changes. Both 2,4-D and 2,4,5-T were members of the phenoxy group of herbicides, the use of which grew rapidly in the post-war years. Applicators used 3.5 million kilograms of phenoxy herbicides in 1950; in 1960, they used 16 million kilograms.[7]

In the 1950s, Dow researchers began experimenting with the pyridine family of chemicals for agricultural applications. Pyridines had been important for a variety of commercial purposes since the turn of the century, when manufacturers isolated them from coal-tar. In response to commercial interest, manufacturers began synthesizing more pyridines in the 1940s, and after the 1950s synthetic processes (based on petroleum and ammonia with relatively high energy inputs) became increasingly important. In the early 1960s, Dow used the pyridine derivative alpha-picoline to produce 4-amino-3,5,6-trichloropicolinic acid, better known as picloram – the active ingredient in its Tordon brand herbicide.[8]

Like phenoxy herbicides, picloram mimicked auxin hormones, was systemic, and was selective for dicots. Picloram was not, however, just another growth regulator. Dow researchers hailed it as "more toxic to many broad-leaved plants" than 2,4-D or 2,4,5-T. Picloram was up to 1,000 times more powerful than 2,4-D and was highly effective against woody plants. And it was *much* more persistent than the phenoxy herbicides. Where 2,4-D and 2,4,5-T persisted for weeks in the soil, picloram persisted for months or years.[9] When Dow marketed the herbicide to the public, it was advertised as "the most powerful weed killer ever developed". It was a "uniquely useful" herbicide that would allow the farmer to "economically and effectively control unwanted weeds that have resisted control up to now", particularly Canada thistle (*Cirsium arvense*), the

[7] N. Rasmussen, "Plant Hormones in War and Peace: Science, Industry, and Government in the Development of Herbicides in 1940s America", in *Isis* 9, 2, June 2001, pp. 291-316; A. Young, *The History, Use, Disposition and Environmental Fate of Agent Orange,* Springer, New York 2009, p. 6.
[8] E. Scriven, R. Murugan, "Pyridine and Pyridine Derivatives", in *Kirk-Othmer Encyclopedia of Chemical Technology*, Wiley, New York 1996; "Seven Heroes of Chemistry", in *Crop Protection Monthly*, 1999, p. 8.
[9] J.W. Hamaker et al., "A Picolinic Acid Derivative: A Plant Growth Regulator", in *Science*, 141, 1963, p. 363; W. Fletcher, R. Kirkwood, *Herbicides and Plant Growth Regulators*, Taylor & Francis, New York 1982, p. 54.

notorious deep-rooted perennial that had been the impetus for noxious weed legislation in nations around the world.[10]

Picloram and the Developed World

Weed science, an off-shoot of agricultural science, blossomed in industrialized countries in the 1960s. Perennial, herbaceous weeds were not a new problem for farmers, but in the second half of the twentieth century they became a greater problem, especially in relatively recently cultivated areas. Perennial weeds had always been more difficult to curtail mechanically because cultivation did not kill perennial as it did annuals. In fact, cultivation spread certain kinds of weeds, such as Canada thistle, that could reproduce from root stocks. Perennials took longer, often decades longer than annuals, to spread and establish. But by the 1960s, perennials were hitting their stride in many places like the American West that had been converted to farming or grazing around the turn of the century. Phenoxy herbicides could kill some perennial weeds, but many of these weeds had life-spans and root-systems that were beyond the reach of even the best extant herbicides in the 1960s.[11]

Picloram's potency, persistence, and mobility in soil made it especially good at killing perennial, herbaceous weeds and wood plants. Its persistence allowed it to stay active through more than one growing cycle, and its soil mobility allowed picloram to leach down and reach the roots of perennials that could be twenty feet deep. For these reasons, picloram was a much superior herbicide for weeds such as Canada thistle, leafy spurge (*Euphorbia esula*), and kudzu (*Puereria lobata*). For certain plants, such as rush skeletonweed (*Chondrilla juncea*) and yellow starthistle (*Centaurea solstitialis*), picloram seemed to be the *only* effective herbicide. The best control was often given by mixing picloram with 2,4-D, which Dow Chemical began selling under the label

[10] Dow Chemical Company, *Tordon 22K: The Man of the Field*, (ca. 1960s), in Box 19, Folder "Herbicides Commercial," MSS 630 Meyer Chessin Papers, University of Montana; C. Evans, *The War on Weeds in the Prairie West: An Environmental History*, University of Calgary Press, Calgary 2002.

[11] J.C. Toney, P.M. Rice, F. Forecella, "Exotic Plant Records in the Northwest United States 1950-1996: An Ecological Assessment", in *Northwest Science*, 72, 1998, pp. 198-209. There is also some evidence that an increase in carbon dioxide in the twentieth century promoted the expansion of invasive perennials. L.H. Ziska, "Evaluation of the Growth Response of Six Invasive Species to Past, Present and Future Atmospheric Carbon Dioxide", in *Journal of Experimental Botany* 54, 381, 2003pp. 395-404.

Tordon 101.[12] Picloram often worked better than 2,4,5-T as well, though again the best control of woody species was often given by mixing picloram and 2,4,5-T, sold under the label Tordon 155.[13]

The most pressing reason to kill brushy plants in countries such as North America, Britain, Australia and New Zealand was that they were "invading" rangelands and pastures, reducing the livestock capacity of these lands. The escalating brush problem on range and pasture in the twentieth century resulted from a number of factors, including fire suppression and exclusion from fire-adapted ecosystems; fencing in of livestock; overstocking of cattle; and periodic drought.[14]Attempts to repel the brush invasion had met with limited or ephemeral success. Mechanical control involved cabling, chaining, or bulldozing unwanted brush and trees. In Arizona, for example, ranchers battered 600,000 hectares of pinyon-juniper plant communities with these methods. However, pinyons and junipers subsequently "reinvaded" much of this area. In other areas, prickly pear (*Opuntia* spp.) replaced brush after mechanical removal, which was not much of an improvement. For other species, such as redberry juniper (*Juniperus pinchotii*) in Texas and eucalyptus in Australia, mechanical removal was ineffective because these species could re-generate from stumps. Mechanical brush control was also expensive in areas where brush was spread out, and became more expensive after fuel prices rose during the energy crisis of the 1970s.[15]

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[12]*Skeletonweed, Chondrilla Juncea L., in South Australia*, Department of Agriculture, South Australia, December 1968; R.W. Couch, D.E. Davis, "Kudzu Control with Tordon", in *Proceedings of the Southern Weed Conference*, 1965, pp. 309; R. Pengelly, R.H. Ferguson, "Overseas and New Zealand Field Results with Tordon", in *Proceedings of the 17th New Zealand Weed and Pest Control Conference*, 1964, pp. 222-228; D.E. Baylor, "Perennial Herbacious Weeds," in *Western Weed Control Conference Research Progress Report*, 1966, pp. 1-16.

[13] H.A. Nation, C.T. Lichy, "Tordon Herbicide for Brush Control in the Southern United States", in *Proceedings of the Southern Weed Conferenc*e, 1964, pp. 287-294.

[14] K.E. Rogers, *The Magnificent Mesquite*, University of Texas Press, Austin 2000, pp. 11-12; P. Binggeli, "The Human Dimensions of Invasive Woody Plants", in *The Great Reshuffling: Human Dimensions of Invasive Alien Species*, J.A. McNeely (ed.), IUCN, Gland 2001, pp. 145-160; S. J. Pyne, *Fire in America: A Cultural History of Wildland and Rural Fire*, University of Washington Press, Seattle 1997; id., *Burning Bush: A Fire History of Australia*, University of Washington Press, Seattle 1998.

[15] J.A. Robertson and CH Pedersen, "Chemical Control of Eucalypt Regrowth", in *Tropical Grasslands*, 7, 1973, pp. 233-237; A.J. Belsky, "Viewpoint: Western Juniper Expansion: Is It a Threat to Arid Northwestern Ecosystems?", in *Journal of Range Management*, 1996, pp. 53-59; R.O. Clemmer, "The Pinon-Pine: Old Ally or New Pest? Western Shoshone Indians Vs. the Bureau of Land Management in Nevada", in *Environmental Review*, 9, 1985, pp. 131-149; D. McKenzie and others, "Chains for Mechanical Brush Control", in *Rangelands*, 6, 1984, pp. 122-127; Balduzzi; "Pricklypear Management in South Texas", in *Rangelands*, 16, 1994, pp. 102-106; R. Lucas et al., "Assessing

Picloram was a great boon to ranchers who wanted to beat back the brush. In North Texas, ranchers and researchers launched the "most massive brush-killing program ever conducted under controlled research".[16] Although the "hope for complete weed eradication",[17] as one newspaper put it, did not materialize immediately, initial research was promising and in Texas *The Cattleman* heartily welcomed picloram to the state where lands were "threatened with business failure because of brush"[18]. In Queensland, Australia, range managers also optimistically forecasted that "the complete answer to timber killing had been found"[19]. From the 1960s on, ranchers in developed countries hacked and squirted picloram into trees, sprayed shrubs with picloram, and bombed rangelands with picloram pellets from helicopters.[20]

Picloram's capacity to kill woody plants was also useful for silviculture and infrastructure maintenance. As with brush problems on the range, brush problems in forests often resulted from human land use, including the suppression and exclusion of fire. In addition, foresters sought to maximize lumber from forests while adhering to notions of sustainable yield. Herbicides were one tool to increase the productivity of merchantable timber stands. In tests, picloram showed promise, and foresters subsequently used picloram to thin conifers, kill trees that had no commercial value (such as fire tree [*Myrica faya*] in Hawaii), and clear sites for tree planting.[21] A final important use of picloram was for infrastructure maintenance. As these countries built more highways, power lines, facilities, and urban areas, the maintenance of problem plants that could interfere with the utilitarian or aesthetic qualities of these infrastructures became increasingly important. Like agricultural work, maintenance work faced both increasing problems from perennials and rising labor costs. Picloram was particularly attractive because its

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Human Impacts on Australian Forests Through Integration of Remote Sensing Data", *Patterns and Processes in Forest Landscapes*, 2008, pp. 213-239.

[16] J. Brown, "New Chemical Doubles Kill: Big Brush Research Plan Announced," in *Wichita Falls Times*, 3 November 1968, p. 18A

[17] M. Akervick, "Most Promising Hope for Complete Weed Eradication," in *Colorado Springs Gazette*, 29 June 1966, p. 2C.

[18] N. Spray, "Tordon: A New Brush Herbicide", in *The Cattleman*, 57, 1971, p. 42.

[19] I. McLean, "Land Clearing of the Tablelands", in *Proceedings of the Weed Society of New South Wales*, 1969.

[20] O.E. Bontrager, C.J. Scifres, D.L. Drawe, "Huisache Control by Power Grubbing", in *Journal of Range Management*, 1979, pp. 185-188.

[21] J.L. Arend, "Herbicidal Uses of Tordon in Forestry", in *Industrial Vegetation Management*, 1, 1969, 9-12; R.D. Ayling, B. Graham, "A Survey of Herbicide Use in Canadian Forestry", in *The Forestry Chronicle*, 54, 1978, pp. 302-308.

persistence could reduce the frequency of visits to areas in need of maintenance, some of which were distant from work centers.[22]

Picloram usage rose in the US and other countries through the 1980s. In 1981, US annual use of picloram was approximately 4-5 tonnes for wheat production; 70-90 tonnes for forestry; 130-160 tonnes for right-of-ways; and 100-120 tonnes for rangeland and 65-80 tonnes for pasture. By 1987, picloram use on pasture and rangeland had doubled to between 270 and 410 tonnes.[23] Picloram use was thus substantial in the US, as it was in Canada, New Zealand, and Australia. It was not as important in Europe, which had less open range and had fewer problems resulting from fire exclusion and the extensification of agriculture. Moreover, perennial weeds and brush troubled the US, Canada, New Zealand, South Africa, and Australia in distinct ways. Weeds of Eurasian origin thrived when introduced to New World temperate zones, where they were freed from the coevolved pests that had kept them in check in Eurasia. For these places, brush problems and weed problems loomed large, especially in the mid-twentieth century, and picloram appeared as an auspicious chemical solution. But poor countries in tropical and subtropical areas in the Americas, Asia, and Africa also faced brush and weed problems. Picloram came to play an important role in these areas, as well, although its role was often markedly – and tragically – different.[24]

[22] For urban infrastructure and weeds generally, see Z. Falck, *Weeds: An Environmental History of Metropolitan America*, University of Pittsburgh Press, Pittsburgh 2011; C.A. Reimer and B.C. Byrd, "Controlling Weeds on Roadsides with Tordon 101 Mixture Herbicide and Norbak Particulating Agent", in *Proceedings of the Twenty-first Annual Meetinf of the Northeastern Weed Control Conference*, Cornell Ornamentals Research Laboratory, Farmingdale (NY) 1967, pp. 401-405; D.J. Morré, "Tordon-2, 4-D Dimethylsulfoxide Combination Herbicides for Use in Roadside Development", Joint Highway Research Project, Indiana Department of Transportation and Purdue University, 1967; H.A. Nation, "Woody Plant Control on Utility Rights-of-way with "Tordon" Herbicide Pellets", in *Proceedings of the Southern Weed Conference*, 1965, pp. 387-391.

[23] For herbicide use numbers and country comparisons, see The International Agency for Research on Cancer, *Occupational Exposures in Insecticide Application and Some Pesticides*, Volume 53, World Health Organization,pp. 483-484, pp. 483-484; Fletcher, Kirkwood, *Herbicides and Plant Growth Regulators* cit., p. 131.

[24] A. Crosby, *Ecological Imperialism: The Biological Expansion of Europe, 900-1900*, Cambridge University Press, Cambridge 2004, pp. 145-170; W. Beinart, K. Middleton, "Plant Transfers in Historical Perspective", in *Bioinvaders: Themes in Environmental History*, White Horse Press, Cambridge 2010, pp. 68-93; Evans, *War on Weeds* cit.; S. Pyne, "Frontiers of Fire," in *Ecology and Empire: Environmental History of Settler Societies*, T. Griffiths, L. Robins (eds.), University of Washington Press, Seattle 1997, pp. 19-34.

Picloram and the Developing World

The concerns and problems of the Cold War, decolonization, and modernization heavily shaped the use of herbicides in Africa, Latin America, and Asia. A few herbicides, including picloram, became dual technologies for both opposing the "wrong" kind of revolution (anti-colonial or anti-capitalist) and fomenting the "right" kind of revolution (liberal modernization). The ideology and impetus for modernization resulted from two factors. One was an intellectual strain that saw societies as moving through teleological stages of development. Another was the political interest of the United States and other Western countries to steer poor nations toward liberal goals and away from communism. In a practical sense, economic modernization often meant agricultural development, which required the funding of agricultural research and technology. A number of organizations pursued these goals, including the UN Development Program (UNDP), the Food and Agriculture Organization (FAO), the US Agency for International Aid, and the World Bank. For many agricultural scientists who were attached professionally or ideologically to these organizations, weeds and brush appeared as heavy weights keeping developing countries from achieving take-off, especially in tropical and sub-tropical areas where the world's poor were concentrated and population growth threatened to outstrip food production.[25]

Increased food production could be achieved through intensification or extensification. In both cases, unwanted plants posed serious obstacles: Trees and brush had to be cleared to extend agriculture; weeds had to be attacked vigorously to intensify production on a plot of land. Intensification of agriculture was the great desideratum of international agricultural modernization – the Green Revolution as it came to be called – which deployed new strains of crops in conjunction with fertilizer and pesticides to increase productivity. Herbicides were particularly important for tropical countries "where weed growth is more rapid and technology less developed"; in these places, as the International Institute of Tropical Agriculture noted, "weed management towers above other considerations related to economic production of basic

[25] M. Latham, *The Right Kind of Revolution*, Cornell University Press, 2011; C. de Haan, "An Overview of the World Bank's Involvement in Pastoral Development", *Pastoral Development Network Paper*, 5, 1994, pp. 1-6; R.D. Child et al., *Arid and Semiarid Rangelands: Guidelines for Development*, Winrock International, Morrilton (AR) 1987.

food crops". [26] In Asia in particular, herbicides were critical to agricultural intensification, and picloram played a modestly useful role in some rice production systems.

More prominent was picloram's use in the extension of agriculture, especially in Africa and Latin America. These continents had low agricultural land density: Africa and Latin America had, respectively, 22 and 11 percent of their cultivable land in cultivation, in comparison to over 80 percent for Asia and Europe. In addition, Africa was poorer (and thus less able to afford expensive inputs for intensification) and made less use of rice, wheat, and corn and hence stood to benefit less from intensive Green Revolution methods. The FAO thus argued that "bringing new land into cultivation remains the most widespread and practical method of increasing food production in tropical Africa and South America".[27]

In Africa, testing and use of picloram to extend pasture and croplands began in the 1960s, where agricultural modernizers found picloram to have "exceptional promise" and hoped it would be cheaper, faster, and less prone to cause erosion than mechanical means.[28] As in the US and Australia, the species composition of many African grasslands shifted toward woodier species in the twentieth century due to the exclusion of fire and browsers, as well as drought and stocking methods that favored woody species. The introduction of woody species from other continents accelerated this species shift. Particularly troublesome were black wattle (*Acacia mearnsii*) and mesquite (*Prosopis* sp.). Black wattle was introduced to at least 25 countries in tropical and subtropical areas. By the end of the twentieth century, East Africa was saddled with 20,000 hectares and South Africa with 2.5 million hectares. Black wattle reduced stream flow, caused erosion and riverbank destabilization, and seriously hindered grazing systems in Africa. Mesquite was also introduced over the entire world. In South Africa, it was considered a useful, ornamental tree until the 1960s, after which concern arose over "alarming infestations". Many

[26] I.O. Akobundu, "No-tillage Weed Control in the Tropics", in *No Tillage Weed Control in the Tropics*, I.O. Akobundu, A.E. Deutsch (eds.), International Plant Protection Society, Corvallis, Oregon 1983, pp. 34.
[27] B.N. Okigbo, "Alternatives to Shifting Cultivation", in *Ceres*, 14, 1981, pp. 41-45.
[28] E.C.S. Little and G.W. Ivens, "The Control of Brush by Herbicides in Tropical and Subtropical Grassland", in *International Journal of Pest Management: Part C* 11, 3, 1965, p. 245.

other species also became increasingly problematic on sub-Saharan rangelands, including Siam weed (*Chromolaena odorata*) and prickly pear.[29]

As in the United States, the best method for clearing brush in Africa in the 1960s and 1970s was often picloram or Tordon mixes, but actual use of picloram and other herbicides used in poor countries, particularly in Africa, is unclear because imports and usage were not recorded. Herbicides were expensive for small farmers, and studies sometimes found the labor savings did not offset this cost. Large landholders and government agencies were more likely to use herbicides. For example, picloram was widely used in rubber and oil palm plantations in Africa and Asia and in cocoa plantations in South America. Beyond this, it was used to extend agriculture and fight invasive species, but the extent of usage is not clear.[30]

The use of picloram in South America was much clearer and more dramatic. Beginning the 1960s, road building in the Amazon opened up new areas to commercial cattle grazing. Ranching had low labor costs and was increasingly profitable as fast food consumption increased in the United States. Herbicides were important for wealthy and corporate ranches (such as those owned by Swift Armour Meat Packing) because they were cheaper than hiring laborers with machetes to cut brush. This also lessened the chance of workers becoming squatters – a major issue for wealthy ranchers. The primary herbicides used in Amazonian forest clearance were

[29] L.G. Holm, "The Role of Weed Control in Agricultural Development", in *International Journal of Pest Management: Part C*, 13, 2, 1967, pp. 90-103; G.W. Ivens, "Possible Uses of Picloram for Rangeland Improvement in Kenya", in *Proceedings of the 10th British Weed Control Conference*, British Crop Protection Council 1970, pp. 418-423; id., "Notes on the UNDP/FAO Kenya Range Management Project", in *International Journal of Pest Management: Part C*, 14, 1, 1968, pp. 16-22; R.M. Lawton, "Bush Encroachment in Zambia," *International Journal of Pest Management C*, 13, 4, 1967, pp. 335-353; National Weeds Conference of South Africa, *Proceedings of the Second National Weeds Conference of South Africa, Stellenbosch, 2-4 February*, Balkema, Cape Town 1977; "Threats", in *Invasives: The Newsletter of the Asia-Pacific Forest Invasive Species Network*, 4, 2006; H. Zimmerman, N.M. Pasiecznik, "Realistic Approaches to the Management of *Prosopis* Species in South Africa", policy brief, HDRA, Coventry 2005. J.M. Goodall and D.J. Erasmus, "Review of the Status and Integrated Control of the Invasive Alien Weed, *Chromolaena Odorata*, in South Africa", in *Agriculture, Ecosystems & Environment*, 56, 3, 1996, pp. 151-164; E.H. Hartmans, *Land Development and Management in Tropical Africa*, International Institute of Tropical Agriculture, 1981, p. 7; F. Sousa de Almeida, "Bush Control in Grassland by Aerial Spraying" in *Proceedings of the Annual Congresses of the Grassland Society of Southern Africa*, 9, 1974, pp. 73-76.

[30] B.H. Bakar, "Invasive Weed Species in Malaysian Agro-ecosystems: Species, Impacts and Management", in *Malaysian Journal of Science*, 23, 2004; K. Moody, H.C. Ezumah, "Weed Control in Major Tropical Root and Tuber Crops – a Review", in *International Journal of Pest Management*, 20, 1974, pp. 292-299; T. Abrahamse, A.M. Brunt, "An Investigation into Pesticide Imports, Distribution and Use in Zambia with Special Emphasis on the Role of Multinational Companies", in *Insect Science Application*, 5, 1984, pp. 157-173.

formulations of Tordon. After forest clearance, ranchers also needed to use Tordon to stem the tide of invasive weeds and brush that encroached upon new pastures. Loggers and miners also used Tordon to create access to the forest for commercial exploitation.[31]

International agricultural modernizers aided this processes in the 1960s and 1970s by funding herbicide research and policy. In response to skyrocketing herbicide use in Brazil in the 1960s, the UNDP, the FAO, and the WHO collaborated to provide scientific study, funding, monitoring, and a regulatory framework for herbicides in Brazil. The four-year program, which received over a million dollars, began in 1968, the same year in which picloram sales shot up to $670,000 – 25 percent of the market share and more than any other herbicide used in Brazil that year. Thereafter other herbicides were more often used on newly cleared lands, but Tordon mixtures remained the dominant herbicides for deforestation.[32]

Modernization and picloram came together in another way in the Amazon as well. In the 1980s, the World Bank helped fund the massive Tucuruí Dam in the Amazon Basin. In order to hurry the dam-building process along and reduce labor costs, the Brazilian government initially contracted with a company that planned to use Tordon to clear the entire reservoir site with Tordon. This contract was cancelled, but Tordon was subsequently used to clear the forested area for the high-tension power lines running from the dam to areas in the Amazon forest that Brazil and development agencies hoped would be even more attractive for development when cheap energy was available.[33]

Picloram was thus an important herbicide in the quest to modernize poor countries. In many of these countries, plants hindered the goals of development. Picloram was well-suited to kill those

[31] J. Skinner, "Big Mac and the Tropical Forests", in *Monthly Review*, 37, 1985, p. 25; D.R. Shane, *Hoofprints on the Forest: An Inquiry into the Beef Cattle Industry in the Tropical Forest Areas of Latin America*, United States. Department of State. Office of Environmental Affairs, 1980; M.J. Eden, D.F.M. McGregor, N.A.Q. Vieira, "Soil Physical and Chemical Properties of Cultivated Pasture on Forest Land, Roraima, Brazil" in *Acta Amazonica*, 21, 1991, pp. 375-390; B. Rich, *Mortgaging the Earth: The World Bank, Environmental Impoverishment, and the Crisis of Development*, Beacon Press, Boston 1995, p. 114; S. Hecht, A. Cockburn, *The Fate of the Forest: Developers, Destroyers and Defenders of the Amazon*, HarperPerennial, New York 1990, p. 49.

[32] J. Yates, "Herbicides and the Regulation of Pesticide Usage in Brazil", in *International Journal of Pest Management*, 17, 1971, pp. 166-174..

[33] P. Fearnside, "Environmental Impacts of Brazil's Tucurui Dam: Unlearned Lessons for Hydroelectric Development in Amazonia", in *Environmental Management*, 27, 2001, pp. 377-396; M. Eden, D. McGregor, N. Vieira, "Pasture Development on Cleared Forest Land in Northern Amazonia", in *The Geographical Journal*, 156, 1990, pp. 283-296; C. Caufield, "Dam the Amazon, Full Steam Ahead", in *Natural History*, 92, 1983, pp. 60.

plants. In particular, the encroachment and invasion of brush on pasture lands in Africa was a great hindrance to agricultural development. In the Amazon, on the other hand, picloram helped to extend development, bringing power to the Amazonian forest and beef to Americans. That was the "right kind of revolution", from a liberal, Cold War perspective. The "wrong kind of revolution", was resistance to the liberal, Cold War order – or its imperial allies. And picloram had a role to play in that revolution as well.

Picloram, Warfare and Ecocide

In 1963, the year Dow Chemical put picloram on the market, it also presented the wonders of the new herbicide to the US Army for consideration as a tactical tool. By 1965, the army had selected picloram as a key herbicide for use in the Vietnam War, and for the next five years the US military used it on a massive scale to defoliate the forests of Vietnam. Defoliation was an essential aspect of the US military's "pacification" strategy (i.e., counterinsurgency) and in this it was presaged by other guerilla wars of the twentieth century. With the possibility of air reconnaissance since the 1920s, forests became critical to guerillas fighting asymmetric wars against more powerful opponents. And so destruction of forests became a major aspect of counterinsurgency. Before Vietnam, however, forest destruction was largely carried out by fire and mechanical means (e.g., bulldozers), as was the case in anti-guerilla warfare in Greece, Morocco, and Algeria. The Vietnam War was not only a much larger and longer war than these guerilla wars, however; it also introduced a new technology for forest destruction: herbicides. This was a brutally literal form of what James Scott has called "seeing like a state". By the same token, the venerable strategy of crop destruction became herbicidal for the first time with the Vietnam War.[34]

The United States' interest in herbicidal warfare began during World War II, when the Army contracted the University of Chicago to test 2,4-D and 2,4,5-T for their usefulness in destroying

[34] F. Anderson, *Is the Use of Herbicides Limited War Justified?* United States Army War College, 1970, http://specialcollections.nal.usda.gov/sites/specialcollections.nal.usda.gov/files/03126.pdf; J.D. Howard, *Herbicides in Support of Counter-Insurgency Operations: A Cost-Effectiveness Study*, DTIC Document, 1972, http://specialcollections.nal.usda.gov/sites/specialcollections.nal.usda.gov/files/00160.pdf, both in Alvin L. Young Collection on Agent Orange, United States Department of Agriculture National Agriculture Library.. J.R. McNeill, "Woods and Warfare in World History", in *Environmental History*, 9, 3, 2004, pp. 400-402; J. Scott *Seeing Like a State*, Yale University Press, New Haven, 1998.

enemy crops. The US did not use any herbicides in WWII or the Korean War, but when US focus shifted to the conflict in Indochina, President Kennedy renewed interest in testing herbicides, setting up a test center in Vietnam in 1961.[35] In 1963, the army initiated a series of "defoliation conferences" to coordinate research on herbicides under a program called Operation Ranch Hand. The conference brought together a number of public and private researchers, including the Hooker Chemical Company, Monsanto, and Dow Chemical. Dow presented on its new product, picloram, showing that it was much more effective than 2,4-D, 2,4,5-T, and Fenuron, another woody plant killing herbicide. Picloram was also safer to handle than these herbicides. For these reasons, picloram greatly interested the Army, and at the Second Defoliation Conference in August 1964, the army and the US Department of Agriculture, along with Dow, presented research projects on picloram that likewise showed that picloram gave excellent results in defoliation trials compared to other herbicides. Dow's research also showed it to be highly effective against crops such as cassava and sweet potato. The third and final defoliation conference in July 1965 again showed picloram to be extremely promising, this time especially against pines. At this point, Tordon 101 was designated "Herbicide White", and later in 1965 picloram was officially selected as one of four herbicides to be used in Operation Ranch Hand.[36]

By 1965, the Department of Defense had promoted Ranch Hand from a research program to a major part of the strategy of the Vietnam War. The expansion of Ranch Hand reflected the expansion and explicit involvement of the US in the war. It also reflected the recognition of the US military that they were fighting against a guerilla army whose strength derived in large part from its ability to hide in the forests and obtain food from the countryside. One of the four herbicides of Ranch Hand, cacodylic acid (Agent Blue), was an anti-crop chemical chosen to reduce food supplies. But the other three herbicides were chemical defoliants, intended to remove the sheltering trees. The military mixed 2,4-D and 2,4,5-T to form Agent Orange and

[35] Young, *Agent Orange*, pp. 24-27.
[36] R. Darrow, K. Irish, C. Minarik, "Herbicides Used in Southeast Asia", *Technical Report SAOQ-TR-69-11078*, United States Army Plant Sciences Laboratory, August 1969, http://www.dtic.mil/get-tr-doc/pdf?AD=AD0864362; *Proceedings of the First Defoliation Conference*, United States Army Biological Laboratories, Fort Detrick, Maryland, 1963, www.dtic.mil/get-tr-doc/pdf?AD=AD0427874; *Proceedings of the Second Defoliation Conference*, United States Army Biological Laboratories, Fort Detrick, Maryland 1964 www.dtic.mil/dtic/tr/fulltext/u2/470094.pdf all from Defense Technical Information Center, Department of Defense; Young, *Agent Orange*, pp. 31-35.

mixed 2,4-D and picloram to form Agent White. Planes and helicopters sprayed large quantities of both Agent Orange and Agent White in the Vietnam War, often for similar targets. Orange, however, was more effective at destroying mangrove canopies, while White was more effective at killing conifers. Orange was more volatile than White and so White was used in windier areas. Orange was faster acting than White, but White was longer lasting and was often regarded a more powerful version of Orange, although the quick action and cheaper price tag of Orange made it the more heavily used defoliant in the war.[37]

The results on the ground were devastating. According to Vietnamese refugees, "the leaves of large trees yellowed, shriveled, and fell; banana plants died; crops withered, rotted, and became inedible… trees were damaged and died [and] fish in ponds and rivers died".[38] In all, the US sprayed 55 million kilograms of herbicides on South Vietnam, resulting in the destruction of a minimum of 20 million cubic meters of timber. The herbicides destroyed 124,000 hectares (41 percent) of coastal mangroves. It is difficult to sort out the effects of particular herbicides, but picloram likely played an important role in fish kills (although scientists at the time did not make this specific connection) and in the destruction of upland, inland forests. 1.3 million hectares of these forests were partly destroyed, with 50 percent tree mortality, and 50,000 hectares "virtually obliterated". The long-term effects included the loss of capacity for swidden agriculture and forest products, as well as the invasion of exotic grasses.[39]

The use of herbicides in the Vietnam War became controversial only gradually, between 1964 and 1968, beginning with opposition to crop destruction and then blossoming into an outcry over the human health and environmental effects of massive herbicide spraying. In 1964, when Operation Ranch Hand was still a relatively small operation, a group of scientists from Harvard signed a letter of protest against the US military's use of herbicides to destroy crops, accusing the military of creating a humanitarian crisis. This and several other letter-writing campaigns slowly put in motion a critical analysis of the use of herbicides in Vietnam. But in the following

[37] J. Stellman, S. Stellman, R. Christian, T. Weber, C. Tomasello, "The Extent and Patterns of Usage of Agent Orange and Other Herbicides in Vietnam", in *Nature* 422, 17, 2003, pp. 681-687.
[38] H. Rose, S. Rose, "Chemical Spraying as Reported by Refugees from South Vietnam", in *Science* 177, 4050, 1972 , pp. 711.
[39] A.H. Westing, "Environmental Consequences of the Second Indochina War: A Case Study", in *Warfare Ecology*, G.E. Machlis et al. (eds.), Springer, New York 2011, pp. 11-17; quote from A.H. Westing in Barnaby, *The Role and Control of Weapons in the 1990s*, Routledge, New York 1992 , p. 72.

two years, the situation in Vietnam and the use of herbicides there changed dramatically. As the war intensified in the mid-1960s, it became clear that the scale and scope of herbicidal destruction was broader than crops. Thus while opposition to crop destruction continued, by 1967 the focus had shifted to destruction of the broader environment – forests and agricultural soils, not just the crops grown on them.[40] The leader of this shift in focus was Arthur Galston. Galston was a renowned botanist from Yale whose critique of herbicidal warfare carried particular cachet since he had invented the chemical precursor of 2,4,5-T. Galston was never opposed to herbicides, which he thought were beneficial to agriculture and hence humankind, but Operation Ranch Hand threatened rather than benefited food production.[41] Galston feared the massive use of herbicides in Vietnam would lead to ecological catastrophe; however, it is important to note that for Galston ecological concerns were always tied to the ultimate human ramifications, rather than the desire to protect nature for itself.[42] There were three dimensions to Galston's ecological fears. The first was simply scale: Herbicides had never been applied in anywhere near these amounts over such a large geographic area. The second issue was persistence: Galston was concerned that the effects would be long-lasting or even permanent. Finally, there was the dimension of scientific ignorance: Many questions could yet not be answered about the environmental and health effects of these herbicides.

While Galston considered all the herbicides used in Vietnam worrisome, picloram was particularly troubling because it was the herbicide about which the least was known, and what was known was that it was very powerful and persistent. Ecologist Fred Tschirley's studies of the effects of herbicides on tropical ecosystems helped arous Galston's fears about picloram. Tschirley carried out experiments funded by the Departments of Agriculture and Defense in Puerto Rico in the mid-1960s to understand how Ranch Hand herbicides would affect tropical ecosystems. One of the key conclusions of his 1968 report was that picloram was "unquestionably" the most effective at long-term defoliation.[43] Later that year at an AAAS

[40]Zierler, *The Invention of Ecocide* cit.; F. Huddle, *A Technology Assessment of the Vietnam Defoliant Matter: A Case History; Report to the Subcommittee on Science, Research, and Development of the Committee on Science and Astronautics*, US House of Representatives, 8 August 1969.
[41] A.W. Galston, "Herbicides: A Mixed Blessing", in *Bioscience*, 1979, pp. 85–90.
[42] Zierler, *The Invention of Ecocide* cit., p. 18.
[43] F. Tschirley, *Research Report: Response of Tropical and Subtropical Woody Plants to Chemical Treatments*, U.S. Department of Agriculture and Department of Defense, February 1968, p. 88, www.dtic.mil/cgi-

conference, Galston condemned the use of picloram for the "great damage" be believed it would cause.[44] Galston continued to express concern about picloram before the US House of Representatives the following year, saying he believed it to be "a herbicidal analog of DDT" and concluding that "its massive application to the soils of Vietnam is going to hamper agriculture, even after hostilities are over, for some time into the future."[45] The scientific uncertainty about the effects of massive herbicide use was compounded for picloram, which had been in use for less than a decade. Even though it was clear that picloram was very persistent and mobile, just how persistent and mobile had not been established.[46] How many miles could it spread? Would it last for months or years? In addition to herbicidal persistence, Galston was concerned that herbicides might ruin the soil, either by soil sterilization (killing useful microbes) or soil laterization (the hardening of tropical soils that sometimes accompanies deforestation). For these reasons, Galston made it clear in a letter to *Science* in 1969 titled "The Lesser of Two Evils" that picloram was the most disturbing herbicide in use in the war. He argued that if the US Department of Defense was going to continue to use herbicides, it should use only the "readily biodegradable phenoxyacetic acids" and not picloram, "since continued large-scale use of picloram could seriously diminish productivity of soils for years".[47]

Galston was not the only person voicing critique of picloram during this time. "Increasingly, the criticism of the military herbicide program in Vietnam by some US scientists has focused on the ecological issue", a report to the House of Representatives stated in 1969. The report made special reference to an article in *Scientist and Citizen* written by Jay Mann and George Harvey titled "Picloram in Vietnam." Mann and Harvey were employees of Monsanto, a rival of Dow, but, according to Mann, they wrote the article without Monsanto's knowledge or blessing. Monsanto made herbicides and was a substantial producer of 2,4,5-T for Operation Ranch Hand. It did not, of course, make picloram, which Dow was the sole proprietor of. Mann, however, was

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bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=AD0675830,from Defense Technical Information Center, Department of Defense.

[44] Huddle, *Technology Assessment* cit., p. 24; "Scientists Warn: Spreading Technology Threatens Our Planet", *New York Times*, 29 December 1968.

[45] A.W. Galston, Statement, Subcommittee on National Security Policy and Scientific Developments of the committee on Foreign Affairs House of Representatives, December 1969, quoted in T. Whiteside, *The Withering Rain: America's Herbicidal Folly*, Dutton, New York 1971, Appendix.

[46] A.W. Galston, "Plants, People, and Politics" in *BioScience*, 1970, pp. 405-410.

[47] A.W. Galston, "Lesser of Two Evils", in *Science*, 1969, p. 373.

not as troubled by the use of these other herbicides in Vietnam, nor was he troubled by the use of herbicides generally. Even more than Galston, he was a hearty supporter of herbicide use to increase crop yields. Although the US military used picloram as a defoliant, the herbicide was also highly effective at killing crop species if they were not grasses. Picloram's potential to destroy crops by contaminating water, soil, and manure deeply troubled Mann. He found it "abhorrent" that herbicidal technology was being used in a way that would damage food production, and more generally, he opposed the Vietnam War.[48] Mann and Harvey's article was a blistering critique of the use of picloram, which they characterized as the "most toxic chemical yet discovered" for plant life. They noted that the US military probably had five million pounds of picloram in its arsenal, and if this amount was "spread uniformly over South Vietnam's forty-two million acres", it would be double the recommended application rate in the United States. In other words, the military had enough picloram to kill off plant life in southern Vietnam *twice*. The article emphasized picloram's "enormous persistency" and high solubility in water because together these characteristics would allow picloram to move through the environment, far from its initial site of application. Picloram could easily get into irrigation systems, Mann and Harvey argued, and like Galston (who they probably influenced) they raised the fear of soil laterization. Mann and George concluded, "The military appeal for this herbicide is obvious: pilots spraying it don't have to return for reapplication. But the Vietnamese farmer does want to return".[49]

Galston, Harvey, and Mann influenced a number of scientists, politicians and journalists who subsequently reported on, and expressed concern about the ecological – and eventually *ecocidal* – effects of picloram. Although some scientists, such as Fred Tschirley, argued that picloram would not cause soil sterilization or laterization, picloram's power, persistence and the uncertainty the stemmed from its short track record made the herbicide a source of continuing concern.[50] Congressmen Robert Kastenmeier, for example, demanded the Pentagon comment on the ecological effects of picloram, citing a news article which claimed that picloram could last up to ten years.[51] Particularly influential was a series of articles by Thomas Whiteside in the *New*

[48] Interview with J. Mann, 11 February 2012, notes in author's possession.
[49] G. Harvey, J. Mann, "Picloram in Vietnam", in *Scientist and Citizen*, 10, 7, 1968, pp. 165-171.
[50] F.H. Tschirley, "Defoliation in Vietnam", in *Science* 163, 3869, 1969, pp. 779-786. Because of its potency, picloram was often described in news articles as a "soil sterilant", but it was not actually marketed or intended for that purpose.
[51] "Kastenmeier Hits Defoliants," *Madison Capital Times*, 3 November 1969, p. 36.

Yorker, which repeated charges that picloram was an herbicidal analogue of DDT. In 1970, Galston suggested that the deliberate, systematic destruction of the environment, what he termed "ecocide", should be internationally outlawed, just as genocide was. The term "ecocide" almost immediately entered the popular lexicon. Through Galston, picloram and ecocide became linked, in popular, scientific, and legislative publications.[52]

At the same time that concern over ecocide in Vietnam was peaking, so was the concern for the direct health effects of Operation Ranch Hand herbicides on people. Although herbicide poisoning had long been a concern, in 1969 a study showed that 2,4,5-T contained an extremely toxic dioxin contaminant, TCDD.[53] In April 1970, the United States government restricted 2,4,5-T in Vietnam and the United States. At the same time, the military was reconsidering the use of picloram due to its extreme persistence in the environment. In 1971, the Department of Defense discontinued Operation Ranch Hand completely.[54]

Herbicidal warfare ended in Vietnam in 1971, but it was just beginning in Africa. In the 1960s, several of Portugal's former colonies in Africa – Angola, Mozambique, and Guinea-Bissau – began struggling for national independence. Portugal responded to these liberation movements with brutality – and herbicides. The details of this herbicidal warfare are cloudier than the Vietnam War, in part because Portugal denied using herbicides during the conflict.[55] The evidence suggests, however, that the herbicidal warfare was carried out from 1970 to 1973 in several of Portugal's colonies, and that the same four herbicides used in Vietnam were also used

[52] For worries about picloram, see: G. Orians, E.W. Pfeiffer, "Ecological Effects of the War in Vietnam", *Science* 168, May 1970, pp. 554; Stanford Biology Study Group, "The Destruction of Indochina", in *Bulletin of the Atomic Scientists*, May 1971; R. Cook, W. Haseltine, A. Galston, "Deliberate Destruction of the Environment: What Have We Done to Vietnam", *New Republic* 10 January 1970, p. 19; A. Westing, Statement, Effects of 2,4,5-T on Man and the Environment, Hearings Before the Subcommittee on Energy, Natural Resources, and the Environment, Serial 91-60, 1970, pp. 109; "Dow Shalt Not Kill: Recruiting for Death", *Villanovan*, 18 February 1970, declaiming that, "in ecological terms (picloram) is much worse than the other" herbicides; T. Whiteside, *New Yorker*, 7, 19, and 22 February 1970. For picloram and ecocide, see: J. Tinker, "Indochina: Ecology which Stockholm Forgot" *New Scientist*, 22 June 1972; B.Weisberg, *Ecocide in Indochina*, Canfield Press, San Francisco 1970, pp. 59, 72; P.Ehrlich, J. Holdren, "Starvation as a Policy", in *Saturday Review*, 1971; Cornell University, Air War Study Group, R. Littauer, N.T. Uphoff, *The Air War in Indochina*, Beacon Press, Boston 1972, p. 92.

[53] TCDD's effects on many organ systems, and its potential carcinogenicity for humans is in dispute. L. Birnbaum, J. Tuomisto, "Non-carcinogenic Effects of TCDD in Animals", in *Food Additives and Contaminants*, 17, 2000, pp. 275-288.

[54] Young, *Agent Orange*, p. 6.

[55] In 1974 General Joaquim Pinheiro, commander of Portuguese forces in Angola, admitted to the defoliation campaign, although he did not elaborate on its extent. "War Called Peril to Angolan Vote: Military Commander Sees Peace as a Condition", *New York Times*, 2 June 1974, p. 8.

in Portugal's war. Unlike Vietnam, however, the herbicides were focused mainly on crops. Campaigns were carried out in Guinea-Bissau and Angola in 1970.[56] According to a doctor for one of the liberation groups in Angola, "The chemical agents acted very quickly on the cassava leaves and on branches and on sweet potatoes, causing them to become completely dry in less than two days. The toxic poisons were also attested to by the badly burned trees in the forest, which looked as if they had suffered a violent fire… Soon the cassava roots and sweet potatoes became soft and mushy; they turned black, as if they had been soaked in bad water for several days. The result was total destruction of all crops affected."[57] In 1972 and 1973 Portuguese forces again used herbicides and napalm to attack villages controlled by rebel groups.[58]

Although it became clear that Portugal was using herbicides, it was much less clear which herbicides were used. Picloram, as Dow and the US military had shown, was incredibly good at killing both cassava and sweet potatoes, so it would have made an excellent choice. Reports from a national liberation group in Angola, and from two officials from nearby Zimbabwe, claimed that picloram, 2,4-D, 2,4,5-T, and cacodylic acid were all being used. A soil scientist who tested an area in Angola claimed to have found evidence only for 2,4-D and cacodylic acid. A mercenary for South Africa claimed that his superiors brought him to an area that was full of barrels marked with Dow Tordon labels and told to mix these with barrels labeled 2,4-D. Whatever the actual cast of herbicides, environmentalists and activists believed that picloram was used in Portugal's counterinsurgent operation, and thus the wars in Angola and Mozambique became one of many lightning rods for agitation against the use of picloram.[59]

Therefore, at the same time that the debate about the use of picloram in Vietnam was winding down, herbicide use in Africa was beginning to be criticized. Anti-colonial activists in the United

[56] G. Bender, *Angola under the Portuguese: The Myth and the Reality*, University of California Press, Berkeley 1978, p. 176; R. First, *Portugal's Role in Africa*, International Defense Aid Fund, 1972, p.18;
[57]*MPLA: Movimento Popular de Libertação De Angola*, Seattle, 1970, available at the Michigan State University African Activist Archive, http://africanactivist.msu.edu/document_metadata.php?objectid=32-130-1922.
[58] W.M. James, *A Political History of the Civil War in Angola: 1974-1990*, Transaction Publishers, New Brunswick 2011, p. 49; G.J. Bender, *Angola Under the Portuguese: The Myth and the Reality*, University of California Press, Berkeley 1978, p. 176.
[59] On picloram's exceptionally good ability to kill cassava (referred to in this report as manioc), see *Proceedings of the Second Defoliation Conference* cit., pp. 138-140; People's Movement for the Liberation of Angola, "Urgent Appeal," *Angola in Arms: Information Organ of the People's Movement for the Liberation of Angola*, Volume 3, 1972, p. 4; Southern Africa Committee, "The Portuguese Territories", *Southern Africa* 4, 9, November 1971, p. 9, available at the African Activist Archive, http://africanactivist.msu.edu/document_metadata.php?objectid=32-130-A0F.

States were convinced that the Portuguese and South Africans were using picloram against national liberation forces in Angola, Mozambique, and Rhodesia. A slew of publications and broadsides in the early 1970s argued that this use of picloram and other herbicides constituted "another form of massacre" and was "genocidal". These publications claimed that the US government, while nominally opposing Portuguese imperialism, was in fact supporting the Portuguese repression by allowing the sale to Portugal (or its colonies and South Africa) of herbicides and aircraft to spray the herbicides with.[60] In a series of hearings in the US House of Representatives in 1973 that resulted from this controversy, the Department of Defense admitted that it had allowed the sale of aircraft and helicopters for herbicide spraying, and that herbicide exports from the US to Portugal had more than quadrupled from 1969 to 1971. However, the Department of Defense maintained that Portugal had made assurances that the aircraft were for agriculture. In the case of herbicides, it claimed to have no authority to regulate exports, and claimed that there was no evidence that the herbicides exported from the US to Portugal were being used in herbicidal warfare.[61] Subsequently, legislators introduced several bills to try to curtail sales of goods used in herbicidal warfare to Portugal, but by 1974 a leftist uprising in Portugal itself had helped end the Portuguese repression in Africa.[62]

Picloram and the Domestic Environment

While concerns about the international use of picloram and other herbicides were dying down, concerns about the domestic uses of picloram were picking up momentum, especially in the US and Canada. From the beginning, picloram's exceptional plant-killing powers and its persistence

[60] Liberation Support Movement, "Genocide! in Angola … and Mozambique", Oakland (CA) n.d., available at the African Activist Archive, http://africanactivist.msu.edu/document_metadata.php?objectid=32-130-117B; Chicago Committee For the Liberation of Angola, Mozambique, and Guine, "Portugal's Desperate Attempt – Chemical and Biological Warfare", Chicago n.d., available at the African Activist Archive, http://africanactivist.msu.edu/document_metadata.php?objectid=32-130-47E. Groups made the accusation that money from Gulf Oil's payments to Portugal for oil in Angola was being used to fund herbicidal warfare, including the use of picloram. See Boycott Gulf Oil Coalition, "Gulf's Ecology: It Is Destroying the Land", Dayton n.d. available at the African Activist Archive, http://africanactivist.msu.edu/ document_metadata.php?objectid=32-130-54.

[61] United States Congress, House Committee on Foreign Affairs *Implementation of the U.S. Arms Embargo (Against Portugal and South Africa, and Related Issues): Hearings Before the Subcommittee on Africa*, United States Government Printing Office, Washington, D.C., 1973, p. 80.

[62] Southern Africa Committee, "Ban on Herbicide Sales Urged", in *Southern Africa* 6, 7, 1973, p. 33, available at the African Activist Archive, http://africanactivist.msu.edu/document_metadata.php?objectid=32-130-A21; A. Isaacman, J. Davis, "United States Policy toward Mozambique since 1945: 'The Defense of Stability'", in *Africa Today* 25, 1, 1978, pp. 36, 43.

and mobility had prompted caution, but until the 1970s these concerns revolved around economic damage to crops, not human health or ecological concerns. While the full regulatory history of picloram is far too complicated to recount – it was different for different herbicide formulations and different places – picloram was more heavily regulated than many other herbicides. These relatively tight regulations were a response to instances where irrigation water or manure had become contaminated by picloram and had inadvertently damaged non-grass crops such as tobacco and tomatoes. The regulations sought to mitigate these problems, not public health or environmental issues.[63]

While the regulation of picloram through the 1970s reflected agricultural concerns, after 1969 the broader public became increasingly concerned about the effects of picloram on public health and the environment as a result of picloram's use in the Vietnam War. In 1969, the little-known International Boundary Commission was thrust into the spotlight after using picloram to kill a 20-foot-wide strip of vegetation along more than 1,500 kilometers of the US-Canada border. The line passed through the middle of the Glacier-Waterton International Peace Park and infuriated superintendents of the parks on both sides of border who had not been consulted. A Glacier Park biologist claimed that the herbicide had contaminated some rivers and lakes in the park, and that there was a good chance it would kill fish and phytoplankton. Opposition to the spray program was widely covered in the media, and critics drew directly on the fears of picloram raised by the still-ongoing herbicidal war in Vietnam. The most strident critic was Gaylord Nelson, a senator and founder of Earth Day, who lambasted the "environmental disaster strip" through "some of the most magnificent wilderness country on earth". Nelson cited Harvey and Mann's article on picloram in Vietnam and argued that the power and persistence of picloram raised the possibility that killing plants in the area would "destroy all food chains" with "indeterminable" ecological consequences on other wildlife.[64] While the boundary-strip controversy suggested North America might be experiencing its own more limited version of ecocide, it also prompted public health concerns about the widespread use of herbicides. A National Cancer Institute epidemiologist reported that the public paid no attention to the 1969 Mrak Report – a seminal

[63] Environmental Protection Agency, *R.E.D. Facts: Picloram*, Washington, DC, 1995.
[64] "Defoliation could hurt wildlife," *Independent Record*, 30 October 1969, p.8; M. Kenney, "Defoliant banned in Vietnam used to set border," *Burlington Daily Times*, 10 September 1970, p. 10C; "The Land: North American DMZ", *Time*, 24 October 1969, p.60; "Sen. Nelson Replies, *"Janesville Gazette*, 21 November 1969, p. 7.

government study of herbicides and human health that came out of the Vietnam War controversies – until a syndicated columnist wrote about the use of picloram on the international boundary and connected picloram to herbicidal warfare and the concerns about deformed Vietnamese babies. Although this was something of a conflation – picloram was not, like 2,4,5-T, a suspected teratogen – the public became quite interested in obscure reports on teratogens and carcinogens.[65] Although the controversy over the boundary died down, it catalyzed a dramatic debate about the role of herbicides in American society. For picloram and several other herbicides, that controversy grew steadily through the 1970s and reached a peak in the early 1980s. During this time, public concerns were shaped by both the scientific understanding of picloram as well as by other cues to its dangers, such as its past role in Vietnam, its regulatory history, and its coincidence with local health problems.

The scientific literature that developed on picloram created both fairly robust understandings of the herbicide and unclear and contradictory findings. Picloram had only begun to be studied when the controversy over herbicidal warfare brought attention to picloram. During the war, this attention focused almost exclusively on picloram's ecological effects, but as the controversy over herbicidal warfare re-oriented toward human health, all herbicides came under scrutiny. In response, chemical companies fired back with research and rhetoric to argue that herbicides were safe. In 1969, Dow scientist Keith Barrons argued in *Science* that, used appropriately, herbicides did not denude areas of vegetation, and they could create habitats that had more wildlife. In 1971, the vice president of Dow, Julius Johnson, authored a paper stating that whatever their uses as military defoliants, picloram and phenoxy herbicides were safe and beneficial for domestic use. Johnson admitted that picloram was persistent, but based on unpublished animal studies from Dow he argued that picloram showed no evidence of being a carcinogen, teratogen, or otherwise a cause of chronic toxicity. He also noted that picloram was water soluble and thus mobile, but for the same reason did not concentrate in fat, unlike DDT. And he pointed out that the phenoxy herbicides had similar, or slightly lower, acute toxicity to mammals than DDT, while picloram was an order of magnitude less dangerous. Both Barrons and Johnson concluded

[65] R.W. Miller, "Teratology in 1970: The National Scene President's Report to the Teratology Society", in *Teratology* 3, 3, 1970, pp. 223-227.

by arguing that herbicides were a nutritional health benefit to people because they increased food production, and there was no evidence they were a public health threat.[66]

The very low acute mammalian toxicity of picloram was never challenged, and it became an important point for proponents of picloram, who often noted that the lethal dose of picloram was lower than table salt. On the other hand, picloram's persistence was also never challenged, becoming a key point for opponents of picloram. Other understandings of picloram underwent greater change after 1970. Picloram's acute toxicity to fish and aquatic life was not exceptional, but combined with persistence it was worrisome. In addition, scientists found that picloram had higher acute toxicity for cold water fish like trout. The US Environmental Protection Agency (EPA) also determined that picloram could bioaccumulate, but the accumulation was nowhere near as high as DDT. By the late 1970s, scientists understood much of these aspects of picloram along with those of other pesticides (Figure 1).[67]

Pesticide	Type	Chemical Family	LD50(rat) (mg/kg)	LD50(fish)(ppm)	Duration of activity (weeks)	Bioaccumulation factor
DDT	Insecticide	Chlorinated hydrocarbon	113	0.007	546	70000
Parathion	Insecticide	Organophosphate	13	0.047	8	9
Atrazine	Herbicide	Triazine	2000	12.6	26-78	0
2,4-D	Herbicide	Phenoxy	400	250	1-4	0
2,4,5-T	Herbicide	Phenoxy	300	0.5	1-12	0
Picloram	Herbicide	Pyridine	8200	2.5	52-78	0

Figure 1. Source: J.B. Weber, "The Pesticide Scorecard", *Environmental Science & Technology* 11, 8, 1977, p. 756-761.

While the acute effects of picloram became clearer, much less was known about its chronic effects in comparison with herbicides like 2,4-D and 2,4,5-T. Thus the controversies over picloram up until the late 1970s focused on the health effects of the phenoxy herbicides that picloram was paired with and on the ecological effects of picloram itself. One of the longest running and most dramatic controversies was over the utility company British Columbia Hydro's

[66] K.C. Barrons, "Some Ecological Benefits of Woody Plant Control with Herbicides", in *Science* 165, 3892, 1969, p. 465; J.E. Johnson, "The Public Health Implications of Widespread Use of the Phenoxy Herbicides and Picloram", in *Bioscience*, 1971pp. 899-905.
[67] Environmental Protection Agency, *Herbicide Report: Chemistry and Analysis, Environmental Effects, Agricultural and Other Applied Uses*, Springfield (VA) 1974; A. Fogels, J.B. Sprague, "Comparative Short-term Tolerance of Zebrafish, Flagfish, and Rainbow Trout to Five Poisons Including Potential Reference Toxicants", in *Water Research* 11, 9, 1977, pp. 811-817.

use of Tordon to clear right-of-ways during the 1970s. Like the border-spraying controversy, this controversy drew on the recent experience of herbicidal warfare to vilify the use of Tordon. Although the main herbicide of concern was 2,4-D, a possible teratogen, newspaper accounts often did not make clear distinctions between 2,4-D, Tordon, and the agents used in Vietnam. In the midst of an attempt by environmentalists to prohibit BC Hydro from using Tordon, vandals attacked the utility company's herbicide barrels with an axe, releasing 750 gallons of pesticide into a nearby stream. Most commentators believed it was an "idiotic" attempt at environmentalist sabotage. BC Hydro responded equally dramatically: In order to combat the "hysterical outburst of alarmist propaganda" about herbicides, BC Hydro president Gordon Shrum drank a glass of Tordon 101 in front of the press to try to convince the public that 2,4-D was safe. (Shrum, who died at the age of 89 in 1985, claimed to suffer no ill effect except a "foul aftertaste".)[68] Shrum's gimmick did not end environmentalist concern – or even the incomprehensible protest tactic of dumping herbicide into lakes, which was repeated in 1978 – and in 1979 BC Hydro was forced into a moratorium as a result of complaints of spraying on private property. For the first time in this controversy environmentalists also expressed concern about the human health effects of picloram: newspapers now stated that the herbicide might cause cancer.[69]

Prior to 1978, picloram had been assessed for teratogenicity (for which there was no evidence)[70] but had not had a proper carcinogenicity test. The National Cancer Institute sought to remedy that, but their study in fact ushered in an era of great uncertainty and confusion about picloram carcinogenicity. The NCI's first study showed evidence that picloram could produce benign liver tumors in female rats (not mice or male rats) at high doses. This was not highly compelling evidence that picloram was a carcinogen, but it also could not be ignored, and it subsequently became the basis for claims like those made in 1979 regarding BC Hydro. The NCI, however, quickly called its own study into question based on the possibility of cross-contamination from an experiment in the same laboratory that included chemicals known to induce similar liver

[68]Bob Bishop, "Protest use of dangerous herbicide," *Squamish Times*, 15 July 1970, p. 10; John Mika, "Why defoliants are used on the Canada-U.S. border," *Lethbridge Herald*, 27 January 1971, p. 26; *BC Sun*, J7 and 8 July 1970; "Cocktail for Two," *Winnipeg Free Press*, 17 July 1970, p.7; G. Shrum, P. Stursberg, *Gordon Shrum: An Autobiography*, University of British Columbia Press, Vancouver 2011, p. 126.
[69] "Toxic pesticide dumped," *Lethbridge Herald*, 5 September 1978, p. 2; "Intervention prevents herbicide application," *Lethbridge Herald*, 24 July 1979, p. 28.
[70] D.J. Thompson et al., "Teratology and Postnatal Studies on 4-amino-3,5,6-trichloropicolinic Acid (picloram) in the Rat", in *Food and Cosmetics Toxicology* 10, 6, 1972, pp. 797-803.

tumors. This confusion was compounded when Martin Reuber, a scientist for the NCI, re-evaluated the study and argued that the results showed that picloram was a carcinogen in *all* of the animal studies. Reuber's superior then publicly called Reuber's analysis into question. Humiliated, Reuber resigned. This, of course, opened the door for both proponents and skeptics of picloram's safety to choose polarized sides of a scientific debate. Dow carried out a better-designed study in 1983, which showed no evidence of carcinogenicity. But given the lack of evidence on humans, and the variety of findings, interpretations, and problems with study design, by the mid-1980s the EPA could only conclude that picloram's carcinogenicity was "not classifiable". With no human epidemiological studies and weak and/or conflicting animal studies, there was simply not enough information to make a judgment.[71]

Better studies in the 1990s suggested more strongly that picloram was not a carcinogen, but it was health concerns about picloram peaked during the late 1970s and early 1980s, when there was still a large degree of scientific uncertainty. These concerns sometimes drew on science. But the uncertainty and complexity of that literature caused confusion and people used other cues to learn about, or signal to others, the danger of picloram. People continued to reference the use of picloram in Vietnam and its association with other herbicides of warfare. In addition, people often drew on the tight regulation of picloram to argue that it was dangerous. This was a practice that had begun during the critique of picloram in Vietnam War, when critics had argued that it was not approved for a single crop in the United States – suggesting that this was due to human poisoning concerns, rather than crop damage. Finally, people engaged in a sort of folk epidemiology, attributing health problems to recent herbicide sprayings. Many local controversies from this time period evidenced these aspects of concern about picloram. When a boy Alabama died with signs "consistent with epilepsy" in the wake of Tordon 101 spraying by the Alabama Power Company in 1982, residents who felt their health was also affected joined in a lawsuit seeking $90 million in damages for negligent spraying.[72] Reports referred to the

[71] Environmental Protection Agency, *Drinking Water Health Advisory: Pesticides*, Washington, DC, 1989, pp. 629-632; United States Bureau of Land Management Oregon State Office, *Supplement to the Northwest Area Noxious Weed Control Program: Final Environmental Impact Statement: Draft*, US Department of the Interior, Bureau of Land Management, Oregon State Office, 1986. On Reuber, see B. Martin, "Critics of Pesticides: Whistleblowing or Suppression of Dissent?", in *Philosophy and Social Action*, 22, 1996, pp. 33-55. There was much more evidence for the carcinogenicity of the picloram contaminant hexachlorobenzene (HCB). The EPA stipulated limits on the amount of HCB in picloram in 1985.

[72] M. Heine, "Complaints fill herbicide's past," *Tuscaloosa News*, 8 August 1982, p.1.

herbicide used as Agent White, and conflated it with Agent Orange. The state toxicologist ruled out the link between the herbicide and the boy's death and the lawsuit was unsuccessful.[73] In the same year, fears emerged of a large cancer epidemic in North Carolina caused by years of picloram spraying. A newspaper article with the headline "Report: Agent White is Causing Cancer" stated that cancer rates had increased rapidly in recent years. The article also quoted Reuber as stating "there is no doubt in my mind that picloram is a carcinogen"[74]. In the North Carolina case, however, the increase in cancer prevalence was eventually attributed an ageing population. When epidemiologists controlled for age, no significant changes in cancer rates emerged. [75] Other cases like these cropped up in headlines across the US and Canada in this period, and although virtually none of them confirmed links between picloram use and serious health effects, they both reflected and kept alive fears about the large-scale use on the environment and human health.

Picloram, Invasive Species, and Environmentalism

Given these issues with picloram, there was no sense, even by the early 1980s, that picloram would be seen as anything other than a potent weed killer – useful for agriculture, but dangerous. For many environmentalists, it remained what it had been since the Vietnam War: A technology that was not beneficial to the environment and was potentially ecocidal. But beginning in the 1980s that sentiment began to change. Over the next 20 years, a number of conservationists and environmentalists came to see picloram as a technology of ecological restoration. Several factors brought about this sea change in perception.

One was the rise of conservation biology, the science of biodiversity. Interest in biodiversity represented, in part, disillusionment with an older paradigm: ecosystem balance. Ecological studies in the 1970s heavily undermined the notion of ecosystem balance, heralding a much more chaotic vision of ecological systems. But the notion of ecosystem balance had been at the core of not just ecosystem biology, but the environmental movement itself. The erosion of the idea of ecological balance, however, did not erode concern for the environment. Instead, many environmentally concerned scientists shifted toward the preservation of biodiversity – of species,

[73] M. Heine, "Herbicide not linked to boy's death," *Tuscaloosa News*, 13 October 1982, p.1
[74] "Report: Agent White is Causing Cancer,"*Gainesville Sun*, 7 June 1982, p. D1.
[75] "Researcher says study valid," *Wilmington Morning Star*, 31 December 1983, p. 6B.

gene pools, and ecosystems. Conservation biologists soon found that one of the greatest threats to diversity – the second greatest threat after habitat destruction – was "invasive species".[76] What exactly was "invasive" was always slippery; usually in a practical sense it meant species that had moved as a result of the great churning of globalization that began in the fifteenth century. A subset of these species became invasive because they did not have natural pests to keep them in check. In short, invasive species were essentially weeds – "environmental weeds", charged with fouling wildernesses and national parks, with creating erosion, and above all with reducing biodiversity.[77]

Also important to the environmentalist perception of herbicides was the rise of restoration ecology. Restoration ecology was also born, in part, out of dissatisfaction with preservation, which had been the impetus for creating national parks and wildernesses. Rather than just setting land aside, which did not work as well as preservationists hoped, restoration ecology argued for a hands-on approach to creating environmental health, one that was both aggressive and grounded in science.[78] One of the major problems that managers of natural areas began to confront in the 1980s was invasive plants. Many invasive plants had rapidly expanded their range and density after the 1960s. This spread stemmed from a number of factors, including poor land management practices, the intensification of farm practices that abandoned land to weeds; and the proliferation of trade and travel between and within countries.[79]

The rise of invasive species, the new priorities and practices of conservation biology and restoration ecology produced a new attitude toward the environment. A 1990 editorial in *Conservation Biology* titled "Eradicating Exotics: The Nasty Necessity" captured the emerging attitude. Beginning in the 1980s the new policy was kill invasive species or else be witness to the slow annihilation of biodiversity. For invasive plants, the practical implications of this approach

[76] L. Glowka, *A Guide to the Convention on Biological Diversity*, IUCN, Gland 1995, p. 45. For changing ideas about ecology and biodiversity, see D. Worster, *Nature's Economy: A History of Ecological Ideas*, Cambridge University Press, Cambridge 1994, pp. 416-420.
[77] J.A. Asher, D.W. Harmon, "Invasive Exotic Plants Are Destroying the Naturalness of US Wilderness Areas", in *International Journal of Wilderness*, 1, 1995, pp. 35-37;
[78] F. Turner, "Cultivating the American Garden", in *Harper's*, 271, 1985; W. Jordan III, "Sunflower Forest: Ecological Restoration as the Basis for a New Environmental Paradigm", in *Beyond Preservation: Restoring and Inventing Landscapes*, University of Minnesota Press, Minneapolis 1994.
[79] C. Bright, "Invasive Species: Pathogens of Globalization", in *Foreign Policy*, 1999, pp. 50-64; "Big Time Weeds Are a Problem, but Not Too Big to Handle", *The Fredrick News-Post*, 3 March 1994; D. Given, "Conserving Botanical Diversity on a Global Scale", in *Annals of the Missouri Botanical Garden*, 1990, pp. 48-62.

meant using herbicides.[80] By the 1990s, newspapers and magazines publications began carrying stories about "botanical barbarians" and self-reproducing "green pollution". Environmental organizations like the Sierra Club and the Audubon society carried these messages, as did The Nature Conservancy, an environmental land management organization which had been using herbicides to combat invasive plants since the early 1980s. Since by this time many of these American environmental organizations now had a global reach, the herbicidal attack – war, indeed, was a metaphor that was used – on weeds became global.[81]

Many of the worst invasive plants were perennials or woody species, and so picloram was used around the world to fight these invasions. It was used to kill prickly pear invasions in Spain, South Africa, and Australia; gorse (*Ulex europaeus)* in the Pacific Northwest, New Zealand and Australia; black wattle in South America; mesquite in Africa and Australia; tamarisk (*Tamarix* spp.) in the American Southwest; *Lantana* in India and Mauritius; and Japanese knotweed (*Fallopia japonica*) in Britain. For certain plants, picloram was the only effective herbicide. For example, in 1987, the Nature Conservancy practice for maintaining their 2,500-acre tallgrass prairie could be condensed to: Early detection, continuous monitoring, and annual application of picloram. For the highly invasive red quinine tree (*Cinchona pubescens*) on the Galapagos Islands, picloram was the most effective herbicide. And in what was probably the first comprehensive attempt to eradicate invasive plants for biodiversity's sake, scientists applied Tordon on numerous species of plants on Raoul Island near New Zealand in 1972. In the US, picloram became the most commonly used herbicide on western public lands, and emblematic wilderness areas like Glacier National Park.[82]

Not all environmentalists accepted herbicides as tools of ecological health, however. A particularly strong anti-herbicide movement emerged in the northwestern US, where activists

[80] S. Temple, "Nasty Necessity: Eradicating Exotics", in *Conservation Biology*, 4, 2, 1990, pp. 113-115; P, Brennan, "Activist Planting Seeds", *Orange County Register*, 28 December 1995.
[81] K.O. Richter, "Exotic Weeds: Biological Pollutants", in *Northwest Parks and Wildlife*, 1994; R. Devine, "Botanical Barbarians", in *Sierra*, 79, 1994, pp. 50-58; D. Schneider, "Slow-motion Explosion: The Exponential Spread of Exotic Species", in *The Whole Earth Review*, 1994, pp. 101; P. Evans, "Weed Killers", *The Guardian*, 3 December 1993, p.14.
[82] B. Winter, "Leafy Spurge Control in a Tallgrass Prairie Natural Area", in *Leafy Spurge News*, 15, 1993, p. 3; D. Hopster, D. Rise, *Glacier National Park Final Report Pesticide Monitoring Project*, Montana Department of Agriculture, June 2003, p. 8; C. Buddenhagen et al., "The Control of a Highly Invasive Tree Cinchona Pubescens in Galapagos", in *Weed Technology*, 18, 2004, pp. 1194-1202; Cooperative Extension Service of Montana, Utah, and Wyoming, *Weed Management Handbook*, 1999-2000.

waged a series of legal battles against the use of herbicides in forestry and rangelands. Beginning in 1977 a group called Citizens Against Toxic Sprays (CATS) sued the United States Forest Service (USFS) over its use of herbicides. The court ruled in favor of the USFS, but while the lawsuit was in progress, the EPA banned the use of the herbicides the plaintiffs objected to, 2,4,5-T and Silvex. The Forest Service shifted to using more 2,4-D and picloram, and citizens subsequently brought more lawsuits against both the USFS and the Bureau of Land Management to halt herbicide application. Like others concerned with picloram and 2,4-D in this time period, the National Coalition Against Pesticides (NCAP, the successor to CATS) referenced the use of these herbicides in warfare and pointed to contemporary studies that supported their belief that these herbicides were dangerous. In 1984, in *NCAP v. Lyng*, the court issued an injunction against all herbicide use by the USFS and the Bureau of Land Management in the northwest region. The ruling, which lasted six years, was heralded as one of the greatest legal victories of the environmental movement, not only among those that brought the case – NCAP, the Oregon Environmental Council, and the Portland Audubon Society – but among national environmental litigators, who saw the injunction as fulfilling the promise of the landmark National Environmental Policy Act.[83]

Although celebrated at the time, in the next decade other environmentalists began to critique the die-hard environmentalist objection to pesticides. Ted Williams was one. Williams was a journalist for *Audubon* whose story on the detrimental effects of pesticides on birds had been reprinted in NCAP's *Journal of Pesticide Reform* in 1997. But looking back in 2003, Williams inveighed that millions of acres of big-game habitat had been destroyed by "noxious weeds that could have been contained" if NCAP had not obtained an injunction against the government's use of herbicides. Williams's disagreement with NCAP was just one striking example of a complex and multi-faceted tension that came to the surface within environmentalism as a result of the controversy over herbicides and invasive species.

One facet of this tension was between human health and the conservation of non-human species or habitats. Environmentalists had long sought to save specific plants, animals, and places from

[83] E.A. Fitzgerald, "Rise and Fall of Worst Case Analysis, The", in *University of Dayton Law Review*, 18, 1992; M.H. O'Brien, "NEPA as It Was Meant to Be: NCAP V. Block, Herbicides, and Region 6 Forest Service," in *Environmental Law*, 20, 1990, p. 735; M.C. Blumm, "National Environmental Policy Act at Twenty: A Preface", in *Environmental Law*, 20, 1990, p. 447.

diminishment or extirpation. But when environmentalism first emerged, the culprit had been bulldozers, or highways, or pollution. These were non-living, exterior threats. Environmentalists fought them by attacking the source – zoning laws, polluting industries, and so on. Invasive species, however, had to be attacked in the environment itself. For those who accepted the "nasty necessity," attacking these invasives required using chemicals designed to poison life, and those poisons could affect other organisms, including humans. Concern about invasive species thus forced environmentalists to make new types of choices. Making those choices, however, meant not only emphasizing preferences – for native plants over human health – but undermining the concerns of those whose preferences were threatening. Environmentalists like Jake Sigg of the California Native Plant Society thus suggested that non-profits opposed to herbicides had "succeeded in creating anxiety" in people, and he hoped to dissuade people from reading NCAP's non-peer reviewed *Journal of Pesticide Reform* and other "pseudoscientific reporting."[84] Likewise, both Ted Williams and the conservation biologist Dan Simberloff accused anti-herbicide environmentalists of being "chemophobes" who exaggerated the risks from herbicides.[85] Other environmentalists challenged the importance of invasive species, arguing that "no single case has been documented of a plant that has gone extinct because of competition with another plant".[86] Similarly, opponents of the use of herbicides for environmental ends accused proponents of being "toxic environmentalists" and dupes of the pesticide industry. Proponents accused opponents of being stuck in an outdated approach to environmental problems and ignorant of the threat of invasive species.[87] Such pronouncements probably not only reflected heretofore implicit criticisms, but may well have magnified them as a way or reducing cognitive dissonance. In that way, the need for environmentalists to reduce the tensions in their own minds may well have increased the tensions between them.

[84] J. Sigg, "The Role of Herbicides in Preserving Biodiversity", in *Fremontia*, 26, 1998, pp. 65-67
[85] T. Williams, "Incite: How to Control Killer Weeds-and Their Many Friends", in *Audubon* 99, 1997, pp. 24-31; D. Simberloff, I.M. Parker, P.N. Windle, "Introduced Species Policy, Management, and Future Research Needs", in *Frontiers in Ecology and the Environment*, 3, 1, 2005, pp. 12-20.
[86] V. Parker, "Guess Who Paved the Way", *Washington Post*, 5 August 2000, p. A17.
[87] "We'd Rather Have Weeds, Missoulians Say", *High Country News*, 17 February 1997; T. Williams, "The Second Century", in *Audubon*, 105, 2003; R.N. Mack, S.K. Foster, "Eradicating Plant Invaders: Combining Ecologically-based Tactics and Broad-sense Strategy", in *Management of Invasive Weeds*, 2009, pp. 35-60; R. Devine, D. Simberloff, *Testimony Before the Subcommittee on National Parks, Forests, and Public Lands and the Subcommittee on Insular Affairs, Oceans, and Wildlife*, 23 March 2010.

Disagreements about invasive species and herbicides also evidenced more abstract tensions relating to how environmentalists thought about the place of humans in nature. For those worried about invasive species, one thing seemed clear: time was running out. Invasive species needed to be dealt with quickly and fully or else the effects would be irreversible. Ecologists in Idaho, for example, bemoaned that public objections to the use of picloram had allowed a new invasive weed to spread to such an extent that the chance of eradicating it was no longer possible. Although pro-herbicide environmentalists believed humans had a role in spreading invasive plants, the very term "invasive" implied an agency that was to some extent beyond the control of humans. Finally, those who were deeply concerned with invasive species saw humans as both dependent on ecosystem functioning and that ecosystem functioning being fragile. Taken together, these beliefs suggested that doing nothing was not an option because invasive species had the power to change ecosystems on their own in ways that would be detrimental to humans. Even if those changes would take a long time they were serious enough to require drastic action now. "What the hell do they really want?" conservation biologist Don Schmitz asked of opponents of herbicides. "Do they want a short-term environmental insult or a long-term ecological catastrophe?"[88]

Those worried about herbicides also sometimes warned of catastrophic effects on human health or the environment; they feared that the effect of herbicides on ecosystems would be irreversible.[89] At other times they painted a dystopia of chronic illness resulting from exposure. Those concerned with herbicides also tended to foreground the effects happening over the course of several years, rather than decades or centuries as those concerned with invasive species did. Finally, herbicidal fears were organized around the idea that problems could be avoided by stopping humans from doing something. In this sense, control over human destiny resided with humans, in contrast to the powerful nature suggested by invasive species rhetoric.

Not surprisingly, the degree to which human health was emphasized reflected group and professional differences. Those environmentalists concerned about the effects of invasive species were often drawn from those interested in particular species – native plant societies, hunters

[88] Williams, "The Second Century" cit.
[89] The *Journal of Pesticide Reform*, for example, used the metaphor of herbicides removing the rivets from spaceship earth. Mary O'Brien, "Oh, Well No Harm Done," *Journal of Pesticide Reform*, 5, 2, 1985, p.0.

wanting to conserve game, and naturalists. Native plant societies often discussed problems with invasive plants and were some of the most vigorous promoters of herbicides.[90] The Rocky Mountain Elk Foundation was also a strong supporter of using herbicide to enhance native grasses for elk habitat, and it is worth reiterating that Ted Williams's remark about NCAP's obstruction uses the term *game* habitat.[91] By the same token, those interested in particular places, such as wilderness areas and national parks, were also often environmentalists concerned about invasive species. This included both conventional wilderness advocates and radicals, like at least one Earth First!er who took up herbicide spraying to try to restore a section of coastal habitat. [92] Scientists charged with studying these species and places also tended to support the use of herbicides. Likewise, the managers charged with maintaining these species and places tended to be open to using herbicides, whether they were government managers of natural areas or employees of the private Nature Conservancy.[93] The group identities of environmentalists opposed to herbicides are more difficult to determine since this group defined itself more negatively. Early on, it appears NCAP was a fairly diverse group. One participant in a protest reported that their politics differed and that their various concerns included "the safety of farm animals, property rights, the welfare of homesteads, human safety". At the same time, the author of the report expressed disdain for hunters and loggers, and other writing in NCAP publications exhibited a middle-class, professional, and urban bent.[94] Outside of NCAP, toxicologists and botanists were well represented among critics of herbicide use for invasive species.[95]

Of course, the tensions created by concern about herbicides and invasive species were complex. Ideas and group memberships did not always fall out neatly along these lines. There was, for example, some middle ground in the idea of integrated pest management (IPM) – the use of biological controls and other alternatives to pesticides along with pesticides. This bridge between camps, however, really hinged on the question of how much herbicide to use. When the *Journal*

[90] *Menziesia: Native Plant Society of British Columbia*, 8, 2, 2003; Sigg, "The Role of Herbicides in Preserving Biodiversity" cit. The Montana Native Plant Society, on the other hand, was a much stronger critic of herbicides on the basis that they were not very effective and killed a lot of native vegetation. E. Kuropat to Montana Department of Natural Resources, 20 September 2004, at http://www.mtnativeplants.org/filelib/54.pdf.
[91] *Bugle: Magazine of the Rocky Mountain Elk Foundation*, Spring/Summer 2011.
[92] P. Brennan, "Activist Planting Seeds", *Orange County Register*, 28 December 1995.
[93] For example, see "Combating the Aliens", in *National Parks*, 74, 2000, pp. 24-27.
[94] "The View from St. Peter's Mountain," *NCAP News*, 1, 3, 1979, p. 6.
[95] For example the University of Montana botanist Meyer Chessin was a constant critic of herbicides from the 1960s through the 1980s. Parker, quoted above, was also a botanist.

of Pesticide Reform profiled IPM projects by the Nature Conservancy, for example, the coverage downplayed the use of pesticides.[96] And in general, groups like NCAP were frequently disappointed with IPM efforts, which overall led to an *increase* in pesticide use.[97] Herbicide advocates, on the other hand, were in favor of IPM, but for many projects they still saw herbicide use as the most important tool, as seen, for example, in the methods used by the Nature Conservancy in their leafy spurge project. IPM was thus not so much a consistent, overall theory, but one that grew out of specific projects, and in many cases those reflected what natural managers had learned over several decades of dealing with invasive plants: Herbicide was an essential tool, often the most important one.

Concerns over herbicides and invasive species thus yielded a glimpse at tensions between human health and conservation, as well as discussions about the place of humans in ecosystems. The issues forced choices that environmentalists had not had to make before, and reconciliation through strategies like IPM were limited. Occasionally, these changing environmental attitudes and tensions were evident in individuals. The environmental journalist Richard Manning, for example, described his Rachel Carson-influenced upbringing and subsequent turn to the "dark side" of pesticides. "*Silent Spring* was gospel to a generation of environmentalists, and we came to hate the chemical plague", he wrote in 1997. "Then some of us came to hate the plague of exotics even more, and we learned to spray Tordon".[98] As Manning's quote suggests, some environmentalists understood their turn to herbicides as a sort of betrayal of Carson. But she may have been more amenable than Manning thought. Carson never suggested that pesticides should be abandoned. She had advocated spot treatments with backpack sprayers. The real change was not in using pesticides, but in the belief that pesticides could be beneficial to the environment – even while still being a concern for public health. In short, environmentalists were faced with issues that challenged the optimistic philosophy of *Silent Spring*, which had indicated that human health and ecosystem health were coextensive, that what was good in the long run would also be good in the short run. What had happened?

[96] L. Vinis, "Restoring Wetlands in West Eugene (Almost) Without Pesticides," *JPR*, 21, 2, 2001.
[97] M. Fooladi, "GAO says IPM has failed to reduce pesticide use," *JPR*, 21, 4, 2001, p. 10..
[98] R. Manning, *Grassland: The History, Biology, Politics and Promise of the American Prairie*, Penguin, New York 1997, p. 189.

First, the Vietnam War pushed many environmentalists to extremes in their rejection of herbicides. In the 1960s the US embarked on a program of herbicidal warfare that probably would have shocked Carson, who died in 1964. It certainly shocked many US citizens who were introduced to the idea of "ecocide" through Arthur Galston and to the troubling health effects of herbicides through the controversy over Agent Orange. As the herbicidal warfare wound down in Vietnam, it surged in Portugal's African colonies. At the same time, a massive herbicidal spraying program was initiated along the US-Canada boundary, catalyzing a discussion about the effects of large scale herbicide use. The boundary dispute was followed by many other controversies over herbicides. Many of these controversies centered on picloram and the phenoxy herbicides used in Vietnam, and well into the 1980s their use as agents of ecocide and links to health problems were noted. Meanwhile, scientific studies often failed to clarify the health effects of these herbicides. The continuing large-scale use of these herbicides on right-of-ways, forests, and range caused fear, anxiety, protests, and lawsuits. Grassroots anti-pesticide groups formed in many areas of the US, most prominently in the Northwest. These groups often had few options for control other than pursuing lawsuits, moratoriums, and bans, some of which were successful. The result was a robust grassroots movement that identified itself by its almost complete opposition to herbicides and other pesticides.

The second development, which Carson also did not foresee, was the increasing problem of invasive species. Carson understood that pests, be they insects or weeds, were problems. And she drew on the biologist Charles Elton's book *The Ecology of Invasions* to point out why pests that had been moved from one place in the world to another could become exceptional problems because they were no longer kept in check by the parasites, predators, and competitors they had evolved with. But she did not see these as threats to ecosystem integrity in the way that many environmentalists increasingly did, both as a result of a dramatic increase in invasive species in some places, and as a result of the rise of conservation biology and ecological restoration. Sensitive to the rising problem of invasives and softened to the idea of ecological intervention, these environmentalist embraced herbicides. Picloram was used to combat invasive species, many of which were precisely the species that farmers and pastoralists in both the developed and the developing world had been spraying with picloram. And it was precisely picloram's powerful attributes – its exceptional killing power and persistence – that made it so valuable against

invasive species. Once the herbicide at the *avant-garde* of systematic environmental destruction, it became the most important herbicide in the chemical arsenal of ecological restoration.

As the land changed, as invasive species spread across the landscape, some environmentalists came to see toxic herbicides as environmental therapeutics rather than threats. Other environmentalists, however, continued to see herbicides as unacceptable. This divide evinced latent tensions within environmentalism between those who prioritized human health risks and those who prioritized ecosystem health. It also reflected different time horizons: short-term versus long-term environmental goals. It was not so much that environmentalists had previously agreed ont hese concerns, but that the environmental issues that arose had not placed those concerns in tension. Nuclear power had posed significant human health *and* ecological risks. Banning DDT did not pose a trade-off between human health and environmental effects in the US (as it in fact did in other countries when it was used for malaria). Individual environmentalists might have emphasized wilderness protection over lead gasoline abatement, but more wilderness did not create more lead hazards. The controversy over invasive species and herbicides, however, illuminated a source of fragility within environmentalism and showed that the comfortable mutualism between human health and ecosystem health that Rachel Carson had optimistically outlined would not always hold.

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